

CLAIMS

1. An integrated optical device comprising a semiconductor substrate in which is formed:
 - 5 an optically active region for generating and confining optical radiation and having an output end for emitting an output beam from the optically active region;
a lens region positioned to receive the output beam from the output end, the lens region having a reduced refractive index and/or an increased
10 bandgap to adjacent substrate material and being shaped to provide a lens effect on said output beam.
2. The device of claim 1 in which the optically active region forms an cavity having a longitudinal axis, the lens region extending along the
15 longitudinal axis and having a lateral extent that varies as a function of distance along said longitudinal axis.
3. The device of claim 2 in which the depth of the lens region varies as a function of distance along the longitudinal axis, the depth being defined as
20 the axis orthogonal to both the longitudinal axis and the surface of the substrate.
4. The device of claim 2 in which the width of the lens region varies as a function of distance along the longitudinal axis, the width being defined as
25 the axis orthogonal to the longitudinal axis and parallel to the surface of the substrate.
5. The device of claim 3 and claim 4 in which both the depth and width of the lens region varies as a function of distance along the longitudinal axis.

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6. The device of claim 1 in which the lens region is an optically passive region.
7. The device of claim 1 in which the lens region includes an optically
5 active structure.
8. The device of claim 1 in which the optically active region and the lens region are immediately adjacent one another.
- 10 9. The device of claim 1 further including an intermediate waveguiding structure between the output end of the optically active region and the lens region.
10. The device of claim 3 in which the lens region comprises a quantum
15 well intermixed region, the degree of quantum well intermixing varying as a function of distance along the longitudinal axis.
11. The device of claim 10 further including a layer of material of varying depth over the lens region, the material enhancing quantum well
20 intermixing in the substrate material in which the lens is formed.
12. The device of claim 1 further including a superlattice structure having a periodic variation in refractive index along an axis orthogonal to the surface of the device, the superlattice extending through the optically active
25 region and the optically passive region.
13. The device of claim 12 in which the superlattice structure further includes band overlap between layers within the superlattice to create a mini-band for transport of carriers.

14. The device of claim 12 in which the superlattice structure further provides a variation in periodic band gap maxima as a function of distance along an axis orthogonal to the surface of the device.
- 5 15. The device of claim 1 in which the optical device is a laser.
16. The device of claim 15 in which the optical device is an edge emitting laser.
- 10 17. The device of claim 1 in which the device is a vertical cavity emitter having a cavity whose longitudinal axis extends substantially orthogonally to the surface of the device.
18. The device of claim 17 in which the lens region is formed in a surface
15 layer of the device.
19. A method of forming an integrated optical device comprising the steps of:
forming an optically active region for generating and confining
20 optical radiation in a semiconductor substrate, the optically active region having an output end for emitting an output beam from the optically active region;
forming a lens region in the substrate positioned to receive the output beam from the output end, the lens region having a reduced refractive index
25 and/or an increased bandgap to adjacent substrate material and being shaped to provide a lens effect on said output beam.
20. The method of claim 17 in which the step of forming the lens region comprises the steps of:

depositing a layer of material onto the substrate, the material being adapted to enhance or suppress quantum well intermixing in an underlying semiconductor substrate;

photolithographically defining said material to provide a quantum well intermixing cap having a lateral extent that varies as a function of distance along a longitudinal axis of said optically active region;

thermally annealing the substrate to locally modify the band gap according to the extent of the deposited material.

21. The method of claim 19 in which the step of forming the lens region comprises the step of:

depositing a layer of material onto the substrate, the material being adapted to enhance or suppress quantum well intermixing in an underlying semiconductor substrate;

photolithographically defining said material to provide a quantum well intermixing cap having a layer thickness that varies as a function of distance along a longitudinal axis of said optically active region;

thermally annealing the substrate to locally modify the band gap according to the extent and depth of the deposited material.

22. The method of claim 21 in which the depth of the lens region varies as a function of distance along the longitudinal axis, the depth being defined as the axis orthogonal to both the longitudinal axis and the surface of the substrate.

23. The method of claim 20 in which the width of the lens region varies as a function of distance along the longitudinal axis, the width being defined as the axis orthogonal to the longitudinal axis and parallel to the surface of the substrate.

24. The method of claim 21 in which both the depth and width of the lens region varies as a function of distance along the longitudinal axis.

25. The method of claim 19 in which the step of forming the lens region
5 further comprises forming said lens region as an optically passive region.

26. The method of claim 19 in which the step of forming the lens region further comprises forming at least part of the lens region as an optically active region.

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27. The method of claim 19 further including the step of forming the optically active region and the lens region immediately adjacent one another.

28. The method of claim 19 further including the step of forming an
15 intermediate waveguiding structure between the output end of the optically active region and the lens region.

29. The method of claim 25 further including the step of forming a superlattice structure having a periodic variation in refractive index along an
20 axis orthogonal to the surface of the device, the superlattice extending through the optically active region and the optically passive region.

30. An optical device substantially as described herein with reference to the accompanying drawings.

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